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Tools to quantify environmental impact and their application to teaching: projects City-zen and HEREVEA

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Abstract. This article presents several strategies to teach university students and professionals in the sector how to reduce the environmental impact of our cities. Firstly, the European City-zen project is summarized and its application to the city of Seville, more specifically to Tirode Linea, a working class neighbourhood, is described; the viability and functionality of the neighbourhood are analyzed and improvements are proposed so that it can become an area that attains zero emissions. Secondly, the HEREVEA project is presented, which developed software for the feasibility analysis and proposals to improve neighbourhoods. Its usefulness is discussed in a case study carried out in the same neighbourhood. Finally, the experience of how to transmit all this knowledge through university teaching is presented.

1. Introduction

A new conception of learning has been imposed in Higher Education, which is more focused on the learner than on teaching [1-3]. One of the elements involved is the process of promoting autonomous, critical, and reflective learning, which is one of the main objectives of the European Higher Education System. The subjects and the curricula should be designed from a perspective that facilitates the training process and the future professional practice of the students and, in this sense, the selection of the most suitable didactic methods to achieve this goal depends on the scientific knowledge of its strategic profile [4]. College students must be proficient in learning to learn. Learning in the university and in subsequent professional activities requires self-regulated learners, capable of managing themselves in an environment that demands making appropriate decisions regarding what and how to learn according to the context and learning objectives. This implies awareness, management, and control of one's abilities [5].

Another important aspect, with the advent of information and communication technology, is that people and, in particular, young generations, use technological tools intensely, which requires constant attention. The disposition of students towards learning has changed; many of these student changes can be attributed to technological developments, which teachers have to face and adapt to [6]. The growing digital technologies have given rise to new learning scenarios that offer people multiple opportunities and resources to learn. This diversity of learning possibilities allows each person to build their own learning trajectory: set goals and objectives, develop their own plans, and choose among the different ways of learning offered [7].

The various types of university students also determine the best teaching methodology that must be taken into account. Currently, students are usually between the ages of 18 and 25. They are influenced by the internet, which is used to obtain the necessary information quickly. So they are very impatient students, who get bored easily, and have little capacity for concentration, as well as few communication and verbal writing skills [6]. The use of new technologies is fundamental, but it must be taught in well guided classes by teachers. There are many studies on learning strategies which show that using new technologies alone, such as computer resources, the internet or complex programs, will not guarantee good results for students [6-7]. There are studies carried out so that students have their own online internet platform with which to work on subjects, which show that the best results are related to students who have more frequent classroom classes a week, and make more use of the platform [7]. Therefore, it must be borne in mind that any new technology to be used as a new learning method must be accompanied by the correct motivation on the part of the teacher, since by itself it is not a guarantee for success. The way that groups of higher education students capitalize on technological resources is fundamental; by using them, the teacher helps students build their own personal learning environment. The key is not only to offer technological resources, but to design activities that invite, guide, and support their construction [7].

In the particular case of teaching sustainability in the construction sector, professionals and methodologies can bring the architecturally qualitative and scientifically quantitative aspects together to reveal the latent potential of our cities and people. These experts must have the necessary communication skills, personalities, and backgrounds to firmly place city stakeholders at the heart of this local and global challenge [2]. This strategy was developed within the framework of the City-zen Project ‘Roadshow’ (a European Union FP7 funded initiative to develop and demonstrate Zero Energy Cities) and the HEREVEA project (funded by Andalusia´s Regional Government), which has developed a software tool for the economic and environmental assessment of rehabilitation projects. Based on the experience applied with university students through the projects City-zen and HEREVEA, a way to reduce the environmental impacts in cities was proposed starting from the transformation, improvement, and recovery of neighbourhoods, and from the way those objectives were transferred to university students and professionals in the sector.

Last fall in Seville, the European project City-zen celebrated two activities, namely the Sustainable Workshops in Architecture & Technology (SWAT) Studio and the City-zen Roadshow. SWAT Studio took place at the School of Engineering of Building Engineering (ETSIE) of the University of Seville, hosting 20 international students who, along with others from the University of Seville who were studying in the Architecture Doctoral Program and the Integrated Building Management Master's Program within the School of Building Engineering, developed proposals aimed at achieving a more sustainable Seville. In the second stage, the City-zen Roadshow took place between 20th-24th November, and international sustainability experts who have already worked in other cities such as Belfast, Izmir, Dubrovnik, and Menorca, addressed sustainability issues in Tiro de Linea, Seville.

The work developed within SWAT was presented by the students at the event “Seville Sustainable City”. The solutions were discussed and developed through the participation of global experts of the City-zen project, and students and local actors drew a plan to obtain a zero energy city, with high environmental quality and energy security. The Roadshow project invited people who knew the city, university staff, master / doctoral students, and professionals (architects, engineers, designers, artists, urban planners, and energy experts) to participate. Different groups dedicated between one hour and 5 days to "Seville Sustainable City" and the participants brought their experience, passion, and energy. The results were finally delivered to the city.

The HEREVEA project was funded by Andalusia´s Regional Government. As part of the activities within the project, a software tool was developed to evaluate the cost and environmental impact of the rehabilitation projects [8]. The software is easy to use and is proposed as a teaching tool that can complement the SWAT and Roadshow activities. HEREVEA uses the Ecological Footprint (EF) indicator [9] to assess the amount of land required to provide resources (grain, feed, firewood, fish, and urban land) and absorb the emissions (CO_2) of humanity. The EF and the Carbon Footprint have become two of the most widespread indicators thanks to the simplicity of their concept and their ability to place sustainability on the world agenda. The EF has been employed in the development of various assessment systems for projects in the construction sector [10-18].

A building in the Tirode Linea neighbourhood of Seville was selected, and the HEREVEA tool applied. The existing pathologies were considered and a study was carried out to determine if it was more viable to repair or demolish it and build a new one. All this was posed in class with undergrads, master's, and PhD students. The teaching strategies and tools are summarized in the following sections of the paper, and the results from these experiences presented.

2. Materials and methods

The teaching strategies to be considered should also take into account to whom they are addressed, more specifically, the university level they will be applied to and the course level, namely 1st, 2nd, or last years of the bachelor's, master's, or doctoral degree students. There are studies that raise these learning differences based on the students' grade [4]. Knowledge of these learning strategies followed by university students belonging to different courses and the effects of the course on the use of the learning strategies are the objectives of these studies. For the approach of a specific methodology, it is essential to know the students to whom it is addressed in order to adapt it to each level.

There are also other factors to be taken into account, as shown in other studies based on surveys about learning applied to university students by other research groups [5]. These studies show that students who have acquired knowledge or who have prepared for learning strategies have better results than other students who have not. In addition, the professors worked in their subjects learning to learn processes, with consensual programming in each degree, and in case it is well organized, other initiatives would not be necessary.

Other researchers [19] have carried out learning experiences based on organizing work groups and practical activities related to technical studies in engineering, construction, and materials. For this purpose, the students were divided into different groups and different universities were also involved. The results obtained and the answers to the surveys applied to the students are very satisfactory. The learning on the part of the students has been very positive. This way, the following section explains how the City-zen and HEREVEA projects can introduce such learning strategies.

2.1. City-zen project

2.1.1. SWAT. The 'Pre-Roadshow Analysis', the SWAT Studio (Sustainable Workshop Architecture +Technology), began 2 months prior to Roadshow. Both SWAT and Roadshow were developed to be intensive by optimizing time, simplifying communication and explanation, and maximising participation (lectures, site excursions, design workshops, and mini-master classes). SWAT is a Master's level student workshop where Building Technology students from the Faculty of Architecture at Delft University of Technology develop and propose innovative, sustainable, contextually sensitive urban design interventions, together with local students of the visiting city. A key ambition of the workshop is to always demonstrate that, through building interventions at all scales ranging from façade, building, street, neighbourhood and district, sustainable lifestyles are possible within existing cities. SWAT is a precursory educational event to the later specialist Roadshow. At the University of Yasar in Bornova (Izmir), SWAT forged pre-Roadshow relationships with key city stakeholders, allowing project sites to be evaluated and selected [2].

2.1.2. Roadshow. City-zen Roadshow travels with a team of internationally recognized experts in the field of energy planning and design to help develop a sustainable agenda for cities and their neighbourhoods. It will visit a total of 10 cities over a 4-year period, cities which are seeking expert guidance on how to become sustainable and wish to move towards energy neutrality. The overall aim of the Roadshow team, who are known as the 'Roadies', is to work closely with people from host cities, whether they are city leaders, neighbourhood associations, energy planners, architects, academics, students, and citizens themselves. The event stays in each host city for 5 days, pre-Roadshow preparations taking at least 2 to 3 months. Local stakeholders are welcomed and encouraged to join and take ownership of the final outcomes. The outcomes will allow the cities' resources, their people, the knowledge and renewable energy potential to be directed effectively by first highlighting the neighbourhoods' lifestyle and energy challenges [2].

2.2. HEREVEA project

The EF indicator adapted to buildings is used for the environmental evaluation of the projects. This indicator has already been used in other publications [20-22], in which the methodology of Solis-Guzman [23] was applied to assess the environmental impact of residential buildings. In the methodology, impact sources are identified in accordance with the bill of quantities of each project, including food expenditure by operators and their subsequent generation of municipal solid waste. Building materials consume fuel or electricity through production processes.

The consumptions produced on site (electricity and water consumptions) are also evaluated [24]. In summary, the EF calculation model determines the total footprint, which in turn consists of different partial impacts: energy (fossil fuel), pastures, fisheries, cropland, forests, and built-up land. These come from the impacts generated by the resources in terms of energy and the generation of CO2 emissions and waste.

Based on this methodology developed by the collaborating team in Seville, ARDITEC, the computer tool "HEREVEA" was implemented to calculate the ecological footprint (EF) and the cost of the rehabilitation projects. It was also used as a teaching tool (see figure 1).

The HEREVEA tool works as a complement to QGIS, an open-source Geographical Information System (GIS) which provides direct access to the data from the Cadastral Electronic Database [25], in order to automatically obtain the initial information (building typology, year of construction, number of floors, etc.) (figure 1).

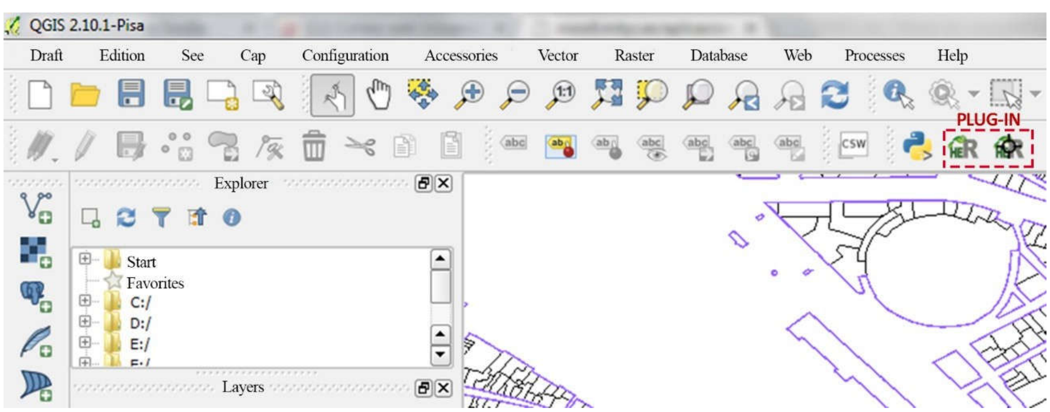

Figure 1. The HEREVEA tool in QGIS.

The user enters other constructive information that is not in the database, such as the type of foundation, structure, height, etc., as well as the interventions to be carried out and the degree of damage (figure 2).

The tool finally calculates the economic and environmental impact of the rehabilitation works. The application for the installation of the plug-in can be downloaded via the following link: http://www.aopandalucia.es/innovacion/principal.asp?alias=con3_s.

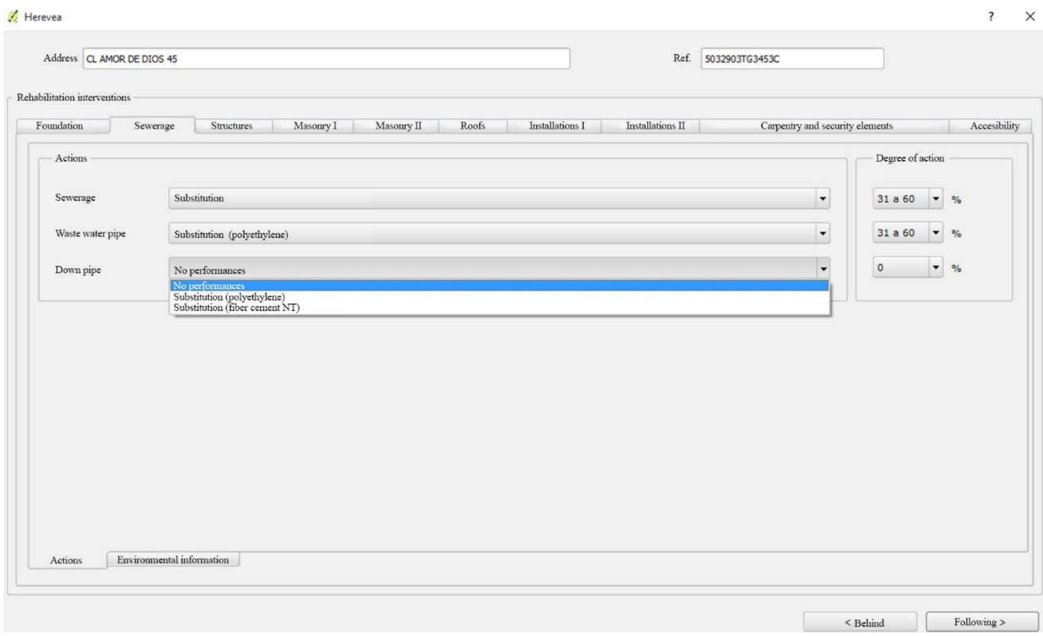

Figure 2. Constructive information and degree of damage per chapter (HEREVEA tool).

3. Methodology

3.1. Teaching process: SWAT

SWAT Studio took place at the School of Engineering of Building Engineering (ETSIE) of the University of Seville, hosting 20 international students who, along with others from the University of Seville, studying in the Architecture Doctoral Program and the Integrated Building Management Master's Program within the School of Building Engineering, developed proposals aimed at achieving a more sustainable Seville (see figure 3).

The activities can be summarized as follows:

1) Acquiring knowledge on the neighbourhood, the architectonic and social aspects.
2) First drafts on the improved neighbourhood, plans, design, installations, etc.
3) Correcting and discussing the proposals with the city town hall representatives.
4) Final oral presentations.

Figure 3. Working groups during SWAT in Seville. Clockwise: professors and students of the Building Engineering School, University of Seville, Urbanism Office of Seville and Delft Technological University, Netherlands; the neighbourhood map divided into working areas; students designing the projects; and the final presentations of their proposals.

3.2. Teaching process: Roadshow

In a 5-Day period, student focussed workshops facilitated an extended and detailed discussion with city stakeholders. ‘FIVE DAYS’ describes the methodology on a day-to-day ‘themed’ basis that guides the evolution of the vision in which expert input would be delivered at key points throughout the five days. ‘PARALLEL’ visually communicates what activities took place. It must be noted that a Roadshow is not intended to be a one-way stream of information and ideas. On the contrary, the method aims to activate, convince, and openly invite and encourage ‘the City’ to be part of the process at any level that they feel comfortable with. The method includes going out of the studio and into the community to engage with various initiatives and to meet and talk with their members.

The final outcomes of Roadshow are graphically presented in ‘VISION’. The timetable is summarized in figure 4. The 5-Day programme was devised in such a way to encourage participants to ‘drop-in’ and ‘drop-out’ so that the Roadshow workshops and mini-master classes could fit into their professional and family schedules, a strategy that would increase city involvement and bolster involvement later in the week.

Figure 4. Timetable of the activities taking place during Roadshow.

Typical co-creative and intensive scenarios from a workshop session, as depicted in figure 5, are incredibly effective in translating what is to come. Coloured markers, rolls of tracing paper, laptops, and notebooks are the tools of choice for the Roadshow participants. Activities have the same aim, namely energy neutrality. However, each component is enjoyably diverse and offers new perspectives and skills on how to attain it. While the two parallel workshops run continually over the week, participants sign up to play a 'Serious Game'. This allows them to have playful fun and experience the cause and effect of energy strategy decisions made at the regional, neighbourhood, and family household scale.

The 'City Vision' takes the form of three overlapping presentations on Day 5. The first briefly outlines the objectives of the City-zen project. The second and third presentations form the major body of the presentation and represent the integrated outcomes of both workshops. The presentation of Workshop 1 would be qualitative in nature and include urban planning intervention proposals at the neighbourhood scale, together with spatial, social, and building regulation strategies. The third and final presentation would be quantitative, focused on energy strategies, scenarios, and carbon offsetting measures.

Figure 5. Roadshow activities in Seville.

3.3. *Teaching process: HEREVEA*

The students were graduates with architectural or engineering technical careers, which is important for the previous knowledge necessary to use the HEREVEA tool. Teaching was divided into two parts: theory and practice. The theory develops concepts about sustainability and environmental indicators. The students come from technical careers, so they must have sufficient knowledge about the rehabilitation and budgeting of construction projects. However, concepts on rehabilitation and repair of buildings are introduced and the systematic classification and criteria of construction cost databases are explained.

In the practical class, an exercise is proposed in which students evaluate the costs and environmental impact with the necessary software and detailed rehabilitation project. The practical session needs, in the first place, a laptop and internet connection in order to be able to perform the practice satisfactorily.

The materials needed for the exercise are:

- the free access program QGIS in its exact version, Pisa2.10;
- the HEREVEA Plugin;
- the user's manual with download and installation instructions;
- the project report, generated automatically by the software, whereby the student can consult the previous concepts necessary for the correct use of the tool.

The practical exercise is developed, which consists of choosing a residential type building, describing its current status and pathologies, and establishing the appropriate repairs. Once the report is obtained, an alternative solution is proposed to the one which suggests that improvements be made from an economic and environmental point of view, i.e., using other more sustainable materials, according to the choices in the software.

A building of the Tirode Linea neighbourhood of the Roadshow was selected and the HEREVEA tool was applied. The existing pathologies were considered and a study was carried out to determine if it was more viable to repair or demolish it and build a new one, considering the inclusion of energy improvements. This was done in class with undergrads, master's, and PhD students.

The HEREVEA tool was applied to a social housing located in the aforementioned neighbourhood; the rehabilitation project is summarized in table 1, where details can be found of the interventions for each of the projects, their pathologies, and the level of damage, ranging from 0 to 100%. The house presents a very serious pathological condition. The damage to the foundations and structural elements presents a high degree of deterioration. Given the integral nature of the action in this case, the interventions included the energy-efficiency improvement of the building envelope and systems, and the accessibility conditions of the common areas of the building.

Table 1. Summary of the pathologies in terms of chapter classification and level of damage.

Chapter/Sub-chapter/Sections	Works	Case of study
03. FOUNDATION / 03R. REHABILITATION		
m^3. Reinforced concrete pads	Foundation underpinning	61 to100
04. SEWER / 04R.REHABILITATION		
u. Sewer	Repair of waterproofing	61 to100
m. Waste water pipe	Substitution	61 to100
m. Down pipe	Substitution	31 to60
05. STRUCTURES / 05R.REHABILITATION		
m^2. Reinforced concrete slab	Repair of compression level	61 to100
06. MASONRY / 06R.REHABILITATION		
m^2. Envelope of brick walls from the outside	Substitution. Energy efficiency improvement	61 to100
	Repair of dampness	61 to100
m^2. Internal partitions	Fissure repair	31 to60
m^2. Envelope of brick walls from the inside	Crack repair. Staple, mesh and plaster	61 to100
	Repair due to fungi and moisture	1 to 30
07. ROOFS /07R.REHABILITATION		
m^2. Horizontal roofs Complete reparation. Energy efficiency improvement		61 to100
08. INSTALLATIONS / 08R.REHABILITATION		
Air conditioning		
Air-conditioning equipment	New installation	100
Electricity		
m. Circuits		61 to100
m. Lines	Replacement	61 to100
u. Light switches/Plugs		61 to100
m. Electric line to ground	New installation	100
Plumbing		
m. Hot water pipelines	Replacement	31 to60
m. Cold water pipelines		31 to60
u. Water heater	Thermal solar heater	100
11. CARPENTRY/ 11R.RECUPERATIONS		
m^2. Doors and windows	Replacement (double glazing)	31 to60
ACCESSIBILITY		
Stairs	Substitution	100
Ramp	New installation	100
u. Elevator		100

The quantification of the basic resources (%weight and emission of materials and working hours) is summarized in table 2. The materials selected are the most representative in the rehabilitation activities carried out. The total working hours are distributed between workers from the different work units (direct costs), auxiliary labour from the indirect costs of the budget, and the operators handling heavy machinery.

Table 2. Quantification of construction materials and working hours.

MATERIAL	Weight (%)	Emission (%)
Sand	40.02	0.16
Cement	25.04	38.87
Concrete	13.52	4.33
Ceramic	12.96	19.46
Steel	4.43	26.55
Paint	0.32	2.66
Aggregates	2.08	0.27
Polyethylene	0.32	1.35
PVC	0.33	1.56
Aluminium	0.15	3.08
Polystyrene	0.21	1.67
Others	0.61	0.03
WORKING HOURS(H)		
Direct cost		68.92
Indirect cost		22.95
Heavy machinery		8.13

The results after applying the HEREVEA tool to the selected project are shown in figure 6, where they are compared economically and environmentally in terms of budget chapters. The EF of the foundations chapter is highlighted; this is due to the major consumption of materials during the process of underpinning, caused by the demands for cement slurry by the poor carrying-capacity of the soil. However, comparatively, the economic result is less important in this chapter.

The damage in the foundation is associated with the need to intervene in other elements that have suffered collateral damage, such as the repair of cracks and fissures in enclosures and interior partition walls, as can be observed in the EF results of the masonry chapter, which stands out with a high environmental impact (figure 6). This is due to the high energy consumption necessary for the transformation and implementation of the materials used in this chapter. From an economic point of view, the masonry chapter has the highest budgetary cost too.

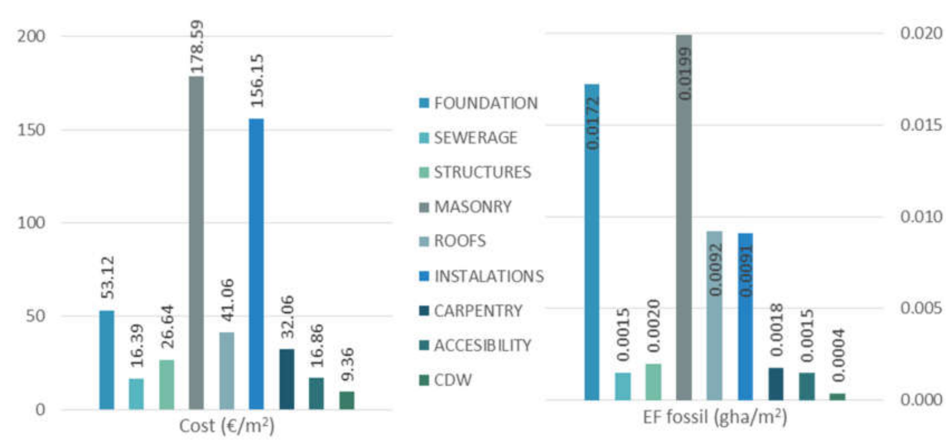

Figure 6. Comparison of the economic and environmental impacts per chapters.

3.3.1. Energy-efficiency improvement comparison. In figure 7, the energy simulation by the CE3 software can be observed [26]. The improvements made to the case study generated a significant reduction in energy consumption during a 25-year period. The initial energy rating E from 0.150 gha/m2 improved to a B rating of 0.018 gha/m2 in the rehabilitated state. This reduction is due to the fact that energy-efficiency improvement actions were carried out in all the elements that influence energy consumption, such as enclosures, roofs, carpentry, and installations.

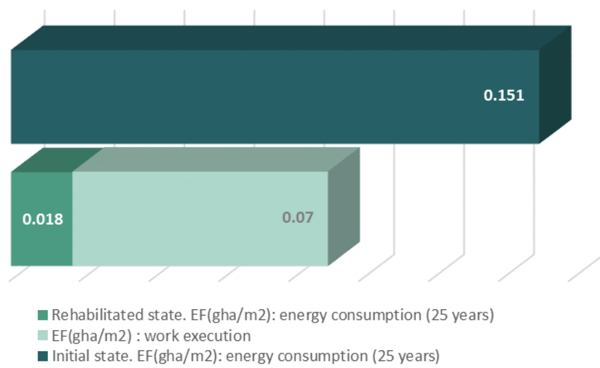

Figure 7. Environmental-impact comparison: total EF of energy consumption and rehabilitation work.

4. Results and discussion

The results of these experiences and in other studies [7] are coincident in that teaching environments which use new technologies and computer tools are strictly necessary to carry out the proposed activities. From an educational point of view, the key is not to offer university students technological media that allow them to define their method of learning, but to design activities that guide and support them in the construction of their own learning pass, and that help to establish synergies between different educational contexts, formal and non-formal, and professional, where they learn and work. The challenge is not technological, but pedagogical [7].

The ability to analyse the influence of the academic activities on the strategic profile of university students is limited. Even due to the importance in the development of learning processes in university education and, especially, of future teachers, research on the strategies used by students, in our case, is scarce. The findings suggest that in order to promote or intervene in the improvement of the strategic profile of university students, emphasis must be placed, above all, on meta-cognitive strategies and on those related to the knowledge and regulation of the affective components involved in the learning process [4].

The society of the future will be highly technological and new generations are becoming deeply familiar with electronic tools. These changes have affected the university. Digital technologies democratize learning by making knowledge accessible to many and by weakening barriers of time and space. The classroom as a place of learning is being challenged and, in some cases, replaced by informal modes of learning [6]. Learning at the university level should involve a variety of teaching methodologies so that teaching will respond to the multiple forms of communication that produce not only text, but also images, movement, and sound [27].

5. Conclusions

Through the City-zen, SWAT, and Roadshow experiences, the students have successfully collaborated with city stakeholders across Europe. Their internationally wide reputation as innovative and impactful event models is growing. They recently became an example of EC 'Best Practice', building upon the visits to 10 cities in total until 2019. In addition, interpreters and student 'facilitators' will join future events.

In the HEREVEA experience, students who have more prior knowledge and who, following the teacher's guidelines, do their homework prior to the practical class, obtain very positive results and have a real advantage from the classes. The teacher must be prepared to correct errors in the installation of the program and the plugin, as well as possible errors that can be made while using the tool. It is important that the teacher insist on the importance of the previous concepts, thus achieving a better understanding and use of the HEREVEA tool.

The methodology proposed in this paper, which is directed at bachelor, master, and doctorate students, aims to teach how to make cities more sustainable, transforming neighbourhoods with zero emissions. For this purpose and taking into account how students need new forms of learning strategies, a different approach is proposed in terms of teaching these concepts. Different work methodologies are proposed, which can obtain better results from the students:

- meetings with professors, city council technicians, in relation to sustainability issues and environmental indicators applied to cities and achieving zero emissions (City-zen project) while also reducing the impacts on building rehabilitation (HEREVEA tool);
- guided tours of the city areas to be studied;
- work groups are organized and guided by teachers;
- the areas to be studied are distributed;
- the tools and computer programs related to the reduction of environmental impact in the rehabilitation of neighbourhoods are provided, and applied to the buildings of the area studied, implementing energy improvements which will contribute to the city having zero emissions;
- support material is provided, such as official reports, general data related to the city, etc.;
- the works are presented in public at the university and in front of city council staff, who can integrate the new trips into real city projects.

In future editions of Roadshow, this previous knowledge acquired will help improve the learning process of students and transmit the innovative ideas to the cities visited, to society and its representatives.

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